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BIODYNAMIC DATA BANK FEASIBILITY STUDY

Carley C. Ward

Civil Engineering Laboratory
Naval Construction Battalion Center
Port Hueneme, CA 93043

June 1982

Approved for public release; distribution unlimited.

Air Force Aerospace Medical Research Laboratory
Aerospace Medical Division
Air Force Systems Command
Wright-Patterson Air Force Base, Ohio 45433

NOTICES

TECHNICAL REVIEW AND APPROVAL

AFAMRL-TR-82-39

The experiments reported herein were conducted according to the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animal Resources, National Research Council.

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

William L. Welde

WILLIAM L. WELDE
Associate Director (Act'g)
Biodynamics & Bioengineering Division
AF Aerospace Medical Research Laboratory

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The report presents an investigation into the feasibility of establishing a biodynamic data base at Air Force Aerospace Medical Laboratory.

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TABLE OF CONTENTS

SUMMARY

A biodynamic data bank at the Aerospace Medical Research Laboratory (AMRL) is recommended. Criteria for the evaluation of a data management procedure are established. Using these criteria, fourteen existing data management programs are evaluated. BASIS, a data base management program developed by Battelle Memorial Laboratories, best satisfies the data base requirements and is discussed in detail.

INTRODUCTION

An ever-increasing volume of digital data is being generated due to the increasing use and capacity of computers. Because the storage cost for digital data is decreasing, the tendency is to store more and more information. It is cheaper to store information on digital tape than on paper. Even on-line storage costs are approaching those for hard copy. One of the most significant improvements in the data processing industry has been in computer storage capacities, which are growing exponentially. The first trillion-bit on-line stores are in use, and new and better electromechanical and solid-state devices are being designed, Reference 1.

Organization of digital information is becoming more important in all areas of business and research. Data management has evolved into a new technology and remarkable advances have been made since the early 70's. Powerful data handling procedures have been devised because business is demanding better programs to keep track of inventory, sales, receipts, and profits. The high programming costs are usually offset by the increase in profits.

These new data management techniques, however, have not been widely used in biodynamic research. Cost is a major consideration; data management programs can be expensive to develop and maintain. Research organizations specializing in biomechanics generally lack the funds, and profit is not as much a motivating factor as it is in business. Although the data management needs in biodynamic research are different, they are no less important.

Biodynamic data are a vital resource, essential for the establishment of human tolerances, the study of trauma, and the design of protective equipment. Test records are especially valuable and should be preserved and fully utilized. Many tests can not be repeated. For example, the use of small primates as test subjects is restricted at some government testing facilities, and the supply of these animals is limited. Data obtained from experiments on human volunteers should be carefully stored and analyzed, so that is is not necessary to repeatedly expose volunteers to potentially dangerous conditions. It is also possible that the use of human volunteers may be curtailed in the future. Cost is another limiting factor in that testing is expensive. The only product produced by this expense is the test record. But even with these restrictions and high costs, it is unlikely that the volume of digital data will decrease. Each new test generates more information to file. To gain the most from each test, the number of measurements is increasing. Increased use of laboratory computers and improvements in instrumentation combine to generate an expanding volume of data.

Organization and preservation of biodynamic data is especially important at major testing laboratories like AMRL. Because progress in biodynamic research is directly related to experimental results, the information is vitally needed by researchers in and outside the government. Test results need to be stored so that they can be compared and shared. The solution being considered is the establishment of a digital data bank.

The original objective of this study was to assess the feasibility of a biodynamic data bank at AMRL. Potential problems were to be analyzed, and recommendations made regarding the basic design and indexing scheme. Considering the overwhelming need for organization and storage of the data, and the available digital data management techniques, a biodynamic data bank is definitely feasible. It is the various data bank options which need to be carefully considered. In this document AMRL's data base requirements are examined. The procedure and programs which will satisfy these requirements are recommended for implementation.

DATA BASE TECHNOLOGY

In this new technology it is easy to lose the reader in the terminology and data management jargon. To maintain a simple frame of reference in this document, a file cabinet analogy is used. Just as written information is filed in cabinets, digital data is stored in a data base. A row of file cabinets is analogous to a data bank. As more and more information is stored, organization becomes critical. Without organization it is difficult to find the desired information and in some cases the information is lost. As in all filing and data organization, it is advisable to select an organization procedure as soon as possible. However, future needs must be anticipated and included in the planning stage. Some flexibility to accommodate unexpected information must be provided. Interrelationships between data need to be defined because they require complex organization schemes. No one procedure or program will satisfy every need perfectly; trade-offs and compromises are necessary.

BACKGROUND

The first data bases (prior to 1960) were collections of digital data stored serially; analogous to a file cabinet where files can be added only at the end of the last drawer. To find a particular record it was necessary to read all files preceding that record. The physical record and logical record were the same, refer to Figure 1.

In the mid 60's, random access was possible, which increased the ease with which records could be retrieved. Logical records could be established independent of the physical storage, as shown in Figure 2. This is equivalent to dividing the files in a cabinet according to category, and being able to add to those files at the end of the category. With this new capability, data bases developed which utilized complex data relationships, such as those shown in Figure 3.

The organization of digital data as we know it today began in 1969 with the Conference in Data System Languages (CODSYL). Task groups were formed to establish languages, objectives, and guidelines for future data handling. They invented the COBOL language. By recognizing data handling problems, they proceeded towards solutions. The phenomenal progress in data base management techniques is due largely to their continuous efforts.

Three basic objectives are stressed by the CODSYL groups: (1) data independence, (2) data security, and (3) minimal data redundance. Data independence means that the stored data, and application programs which use them, are independent. Either may be changed without changing the other. Data security means that the data is protected against unauthorized access, loss, and change due to tampering. Records of data updates are maintained. Minimal data redundancy or controlled redundancy means that the storage of the same data in more than one location is avoided if possible. With the low cost of storage, this requirement is becoming less important. However, updating can be a problem if data is stored in multiple locations. To accomplish these objectives, a new approach to data handling evolved. Direct access to the stored data had to be eliminated, all access being performed by a data base management system (DBMS), Reference 2. In the file cabinets analogy, these programs are equivalent to automated file clerks. The clerk is entrusted with the cabinet keys and rigidly follows regulations, handling all requests and file maintenance. This function is illustrated in Figure 4.

PRESENT DBMS CAPABILITY

Most of the large DBMS's developed since 1975 meet some or all of the CODSYL requirements, Reference 3 and 4. However, some data handling specialists feel that the CODSYL requirements are too restrictive, Reference 5-9. But all ascribe to the general principles as stated by James Martin (Reference 1) in his definition of an ideal data base. He defines data bases to be collections of interrelated data stored together without harmful or unnecessary redundancy to serve multiple applications. The data should be stored so that they are independent of the programs which use the data. A common and controlled approach is used in adding new data and in modifying and retrieving existing data within the data base. The data is structured so as to provide a foundation for future application development.

Interrelationships between data in the logical data base description are referred to as the schema structure. Schema are divided into four general non-exclusive categories; non-exclusive because with minor changes it is often possible to convert from one to another. These schema structures are:

1. Hierarchical or tree structure
2. Network, plex or CODSYL
3. Inverted file
4. Relational

Simple examples of the schema structure for testing records are shown in Figures 5-8. Hierarchical structure (Figure 5) should be used if it is common to search using the test number. Network structure (Figure 6) is more flexible and has advantages when the search involves interrelated data. Inverted file structure (Figure 7) is useful when the search is on a particular attribute, such as a search for all tests above a specified acceleration level. Network or plex structure schema can usually be converted to inverted file or hierarchical form, but the search and update algorithms are not likely to be as efficient. Relational structure (Figure 8) is equivalent to storing tabular data keyed together with an identification number. In the example, it is the test number. Relational structure is combined with the preceding three structures in business applications, where tables of data are required. In general, relational data base programs are less flexible with respect to searching, Reference 10.

DBMS usually specializes in one schema structure with some capability in one or two of the other schemas. Each program is different and no one program will meet every need. A complex array of alternatives are provided.

The trade-offs to consider involve computer time, storage space, maintenance, data independence, and ease of usage. Packing density reduces the retrieval speed but increases the maintenance costs. Efficiency is inversely proportional to the complexity. The more complex a program is, the more difficult it is to recover and maintain. Data independence tends to make the program less efficient.

A group of general purpose data base programs have evolved in the past 8 years. In these programs, relationships between data are specified by the user and can be changed during the life of the data base. Although their efficiencies and capabilities vary, they all provide the following services:

a. Retrieve requested digital records and related information
b. File new records
c. Delete old unused or incorrect records
d. Verify or check new records
e. Restrict unauthorized access to data
f. Restrict unauthorized updating or editing of files
g. Summarize data

In addition, some programs prepare written reports and perform statistical analysis. A few have varying format capability so that data can be input directly into user programs.

AMRL BIODYNAMIC DATA BANK REQUIREMENTS

A computer program will be required to manage AMRL's biodynamic data bank, and to serve as an intermediary between the data and the users of the bank. The direct transfer of data shown in Figure 9 will be changed to the data handling diagrammed in Figure 10. Data from the testing laboratories, accident data, material properties information, and other biodynamic data will be stored. The data bank users will include biodynamic modelers and other interested researchers.

This DBMS can be either written or purchased, and the schema structure can vary in complexity. A highly interrelated network or a simple abstract storage program can be used.

WRITING A DBMS

Writing a special purpose DBMS is expensive. The flexibility required to store biological test results and the large volume of data make even a simple management concept difficult to code. Adding to the programming expense are costs associated with documentation and eventual error investigation. Cost of writing a complex program which is data dependent will exceed $250,000.* Data independence would raise the cost to several million dollars.* But even for a simple abstract storage program, where the search is on key words and word stems, the cost would approach $100,000.* In such a simple program, the digital test data would have to be stored at a less accessible level.

The risk of failure associated with writing a DBMS is high. Data base programming requires a special skill and any turnover of programming personnel could be disastrous. Obsolescence is also a consideration. Unexpected

*Estimate provided by the Control Data Corporation data base programming specialist, Dennis Degner.

requirements for the data base will develop in the future. It is difficult to accommodate these changes unless the same programmer is retained. Based on the recent progress in data base management, changes in procedures and storage devices must be anticipated. In summary, a data base failure could result from any of the following: inept programming, turnover of programmer personnel, unexpected changes in equipment, and revised data base requirements.

PURCHASING A DBMS

Purchasing a general purpose data management program has less risk, provided the program is carefully selected. Since the development cost is distributed between the users, a far better program can be purchased than can be written for the same dollar amount. Documentation of a purchased program is generally very good because it helps sell the program. Updating is less of a problem because the vendor has a continuing commitment to the program. In the past some data base management companies have provided upgraded versions of their DBMSs at a reasonable cost or free of charge, References 11-13. The improvements made to the program are designed to have little or no impact on the stored data. Some data base companies will also maintain the program for a fee.

SELECTION CRITERIA

The program must meet the AMRL needs and provide the service shown in Figure 10. These needs are not at all similar to those of business. Data generated at AMRL has little commonality and is relatively unstructured compared to business records. Centrifuge, vibration, and sled test records are all different. Accident data and material property information have their own forms ranging from single constants to multi-page reports. Storage of textual and numerical records will be required. In order to manage this data, the program must be flexible and accept variable length records. Most typical business DBMSs can not provide this capability.

AMRL uses Control Data Corporation (CDC) computers in their central computer facility. To avoid a costly and troublesome conversion, the selected DBMS should be operational on this computer. It is the only computer easily accessed by all of the testing groups and data users. Since most DBMSs are written for business machines (IBM equipment), this requirement limits the choice of programs.

Costs to buy, implement, and operate the program should not be excessive. Operating costs should include costs to update, edit, file, store, and retrieve data. Because the users at AMRL do not pay for machine time, manpower costs are most important. Ease of usage should be stressed.

Reliability should be considered and evaluated. A widely used program has greater reliability. Errors and problems should have been discovered and corrected. A DBMS which has been used in a similar application is preferable. Maintenance and guarantees provided by the vendor add to the program's reliability.

User acceptance is an important factor and is directly related to the success or failure of the data base. The program should provide a service to the groups generating the data as shown in Figure 11. The improvements in efficiency and the convenient storage provided by the DBMS should compensate for the added effort required to prepare the data for the bank. Report preparation and record summaries are helpful in this regard. Flexibility to format the retrieved data for reports or other programs is also helpful.

PROGRAM EVALUATION

Using the preceding criteria, fourteen widely used and reliable programs were evaluated, refer to Table 1. The information in Table 1 was obtained from References 11-22 and from literature provided by DBMS vendors. The primary requirements, capability to store variable length records, and the ability to run on the CDC computer eliminated most of the programs from consideration. Only TOTAL, DMS 170, SYSTEM 2000, MODEL 204, and BASIS meet these requirements, refer to Table 1.

DMS 170, MODEL 204, TOTAL, and SYSTEM 2000 manage interrelated collections of data values and are used primarily for business applications. Although the record length can be changed, the record must be structured. Indexes or keys must be used in the search. These programs are business oriented programs, for storing bills of material, accounts receivable and other structured records. DMS 170 and MODEL 204 were eliminated because they can not process textual data. TOTAL or SYSTEM 2000 could be used, but they would be very restrictive. The biodynamic data records would have to be structured to fit the program. Also SYSTEM 2000 is expensive to update.

BASIS, on the other hand, meets all of the primary requirements and handles unstructured records (Table 1). It stores and retrieves both textual and numeric information. Sort can be on any data, partial data, or several data elements. Words or word stems can be used. In BASIS the user can tailor the data base structure to define specific retrieval needs. Document retrieval also includes on-line sorting, user-designated thesaurus, inverted file (Figure 7) or sequential file searching, field mapping, hierarchical searching (Figure 5), and numerous display and printout options. Persons without experience in computer programming can easily search the data base according to John Stetz of Control Data's Data Management Consulting services.

BASIS -- THE RECOMMENDED DBMS

BASIS is a general purpose DBMS developed by Battelle Memorial Laboratories of Columbus, Ohio. Versions of BASIS have been in use at Battelle since 1969. The program has been improved and upgraded until it is one of the most flexible user-oriented programs available. Battelle has invested millions of dollars in the program and maintains a team of data base experts to make improvements and program new options. Its ability to handle textual data is unequaled and its report generation options are excellent.

It can be operated on-line or using batch input. Four levels of security are provided: (1) fetch and display, (2) add, fetch and display, (3) modify or change existing data, add and delete, and (4) full authority (Wizard).

BASIS is an excellent program for applications with varying retrieval and reporting requirements. The user has the ability to interface BASIS with user coded programs or with statistical programs like SPSS. Execution of these post-processors is accomplished with the RVN command in BASIS. Because the data can be provided in the desired format or report form, a reciprocating exchange of data is possible. The transfers and accesses will resemble that shown in Figure 11.

This DBMS has been used in several hundred data bases. Current applications include the following: transportation research information system, laboratory animal data base, aviation safety reporting system, litigation systems, client tracking system, chemical abstracts condensates, library search and circulation, personal information, material information systems, and alcohol information retrieval system. Because BASIS is now available worldwide via the CDC CYBERNET Service network, and supported by CDC Data Management Consulting Services, usage of the DBMS is rapidly increasing.

The major advantages of BASIS (Reference 22) can be summarized as follows:

1. New applications can be implemented quickly.

2. No programming is required in many cases to load a data base.

3. Excellent mass storage efficiency due to BASIS compressed record format.

4. Index file structure permits growth in data base without significantly impacting response time.

5. Excellent for applications with varying retrieval and reporting requirements.

6. Extensive flexibility in defining applications -- indexing options, display labels, dialogue modifiable, etc.

The initial cost for BASIS is high (approximately $100,000), representing a considerable investment. AMRL must weigh this cost against the services provided and possible alternative programs like SYSTEM 2000 and TOTAL. Certainly the value of the data is sufficient to warrant the investment; but is the greater flexibility, ease of use, report generation, etc., worth the additional cost? The alternative is to structure the data, which is also expensive and tedious. Considering this alternative and the advantages reported in the previous paragraphs, BASIS is recommended for this application.

BASIS should be able to accommodate any future AMRL data bank needs, since it can manage large volumes of data and text. Also, the program is well maintained and updated by Battelle Labs. In the event that the AMRL data bank is expanded to a national biodynamic data bank, the program will be more than adequate. The flexibility provided will allow the inclusion of data from other sources with minimum data changes. Data suppliers and users of a national bank should like BASIS, as it is a widely used and accepted DBMS.

CONCLUSIONS

A data bank of biodynamic data is feasible at AMRL and is highly recommended. Just as reference books and journals are stored in a library, digital records containing reference data need to be stored in a data bank. To effectually manage such a collection of data, a computer program (DBMS) is required.

Biodynamic data management requirements are different from the usual business requirements. Relatively unstructured, variable length records will be stored which include large amounts of textual information. Because of data base programming complexities, it is recommended that a DBMS be purchased, not written. But few programs are capable of handling variable length records and are operational on the CDC computer. Of these, only BASIS meets all of the data bank requirements. This widely used DBMS is a flexible, but powerful program.

BASIS is a user-oriented program. It is easy to retrieve and store data, and the user is provided with a range of capabilities and schema options. The program operates on-line or in the batch mode. User programs, post-processor graphics, and statistical packages can be interfaced directly with BASIS.

These services, provided to the data user and suppliers, contribute to the success of a data bank.

In conclusion, this study determined BASIS to be the best DBMS for a AMRL biodynamic data bank.

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Table 1. Evaluation of Fourteen Widely Used Data Base Management Programs.

DBMS	AMRL Requirements				Cost in $1,000's	Primary Schema	DBMS Vendor
	Operational on CDC Computer	Variable Length Record	Can Process Unstructured Data	Can Process Textual Data			
BASIS	yes	yes	yes	yes	70-100	inverted file hierarchical	Battelle
TOTAL	yes	no	no	yes	18-52	CODASYL/network	Cincom
System 2000	yes	yes	no	yes	35	inverted file	MRI
DMS 170	yes	no	no	no	32	inverted file	CDC
Model 204	yes	no	no	no	28	inverted file	Computer Corp. of America
SEED	yes	no	no	no	9-11	CODASYL/network	International Data Base Sys. Inc.
INQUIRE	no	no	no	no	65-130	network	Infodata Systems Inc.
RAMIS II	no	no	no	no	34-60	network	Mathematical Products Group
ADABAS	no	yes	yes	yes	132	inverted file	Software Ag. of North America
IMAGE/1000	no	yes	no	no	50	CODASYL/network	Hewlet Packard
DBMS-10 or 20	no	no	no	no	27	CODASYL/network hierarchical	DEC
IMS/360 IMS/VS	no	yes	-	no	-	hierarchical	IBM
IDMS	no	-	no	no	45	CODASYL/network	Cullinane Corp.

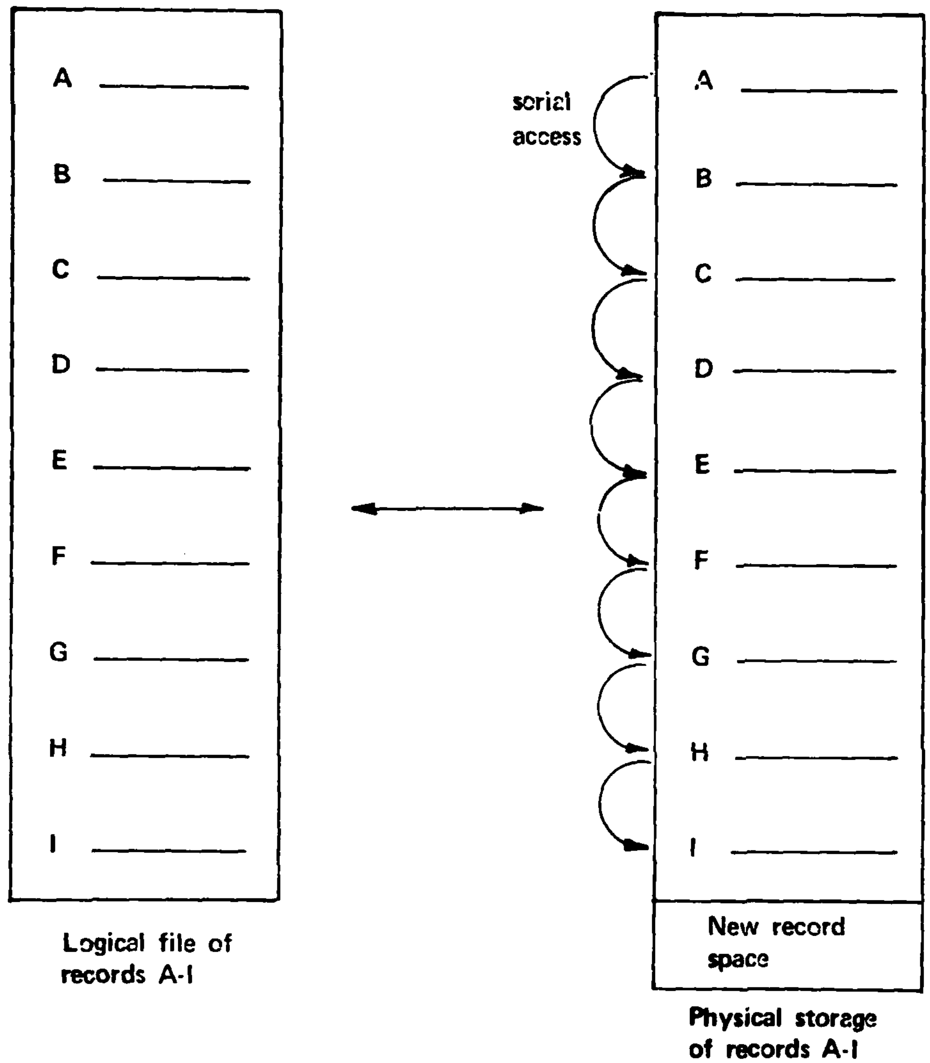

Figure 1. Early data record storage, serial access method.

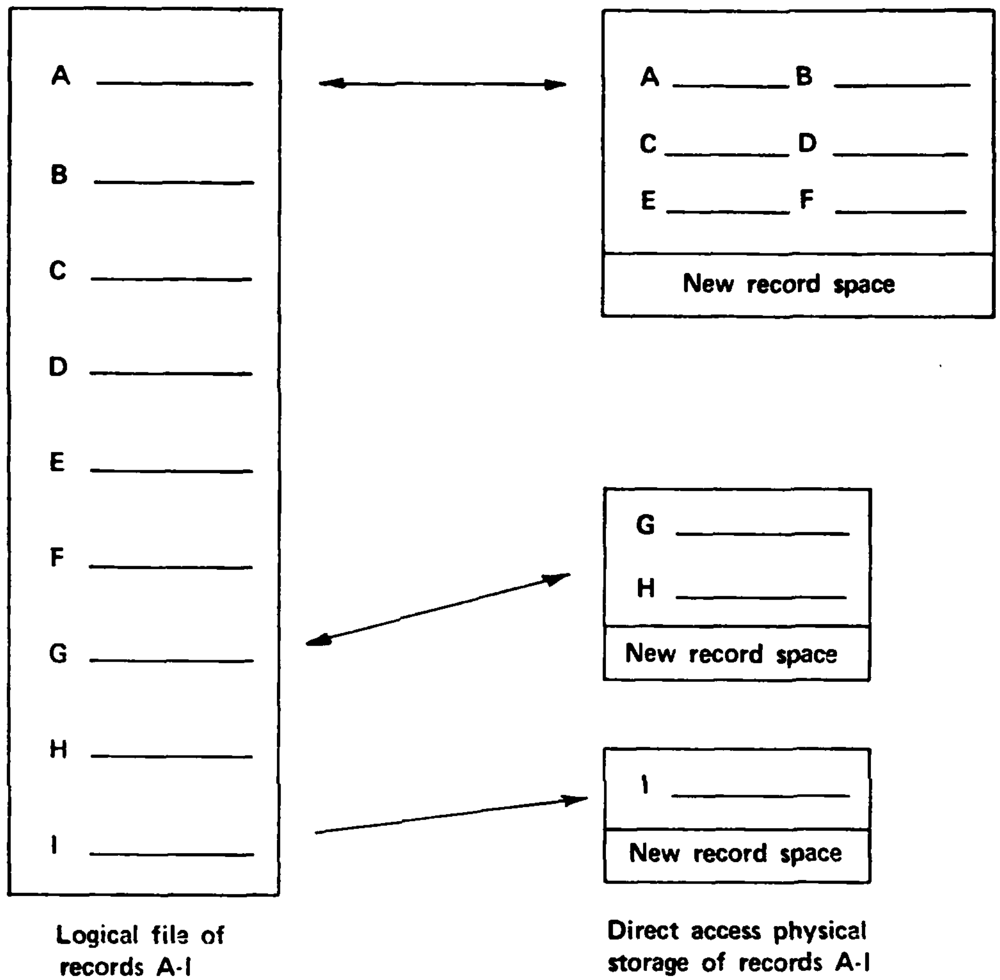

Figure 2. Late 60's file access method.

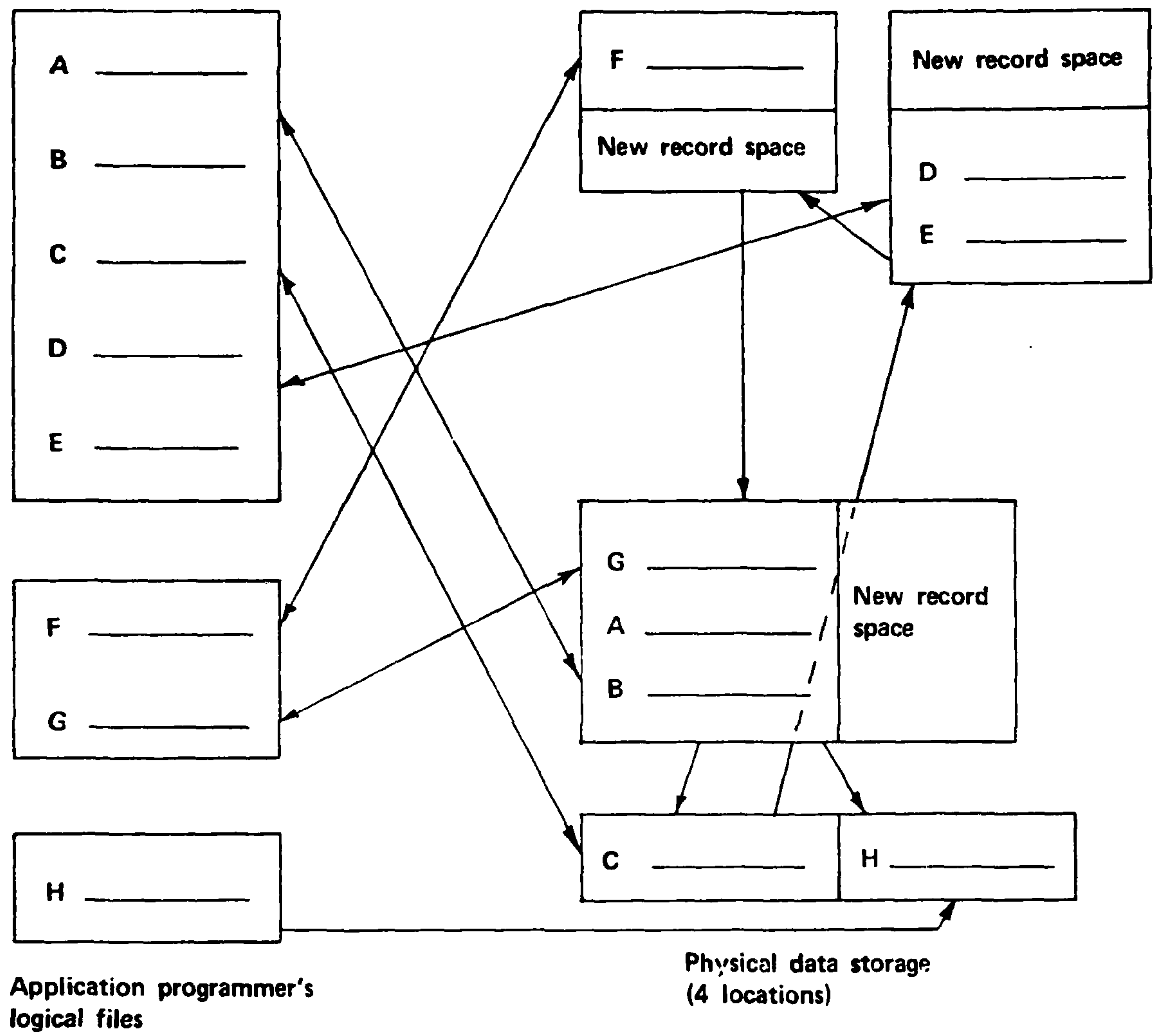

Figure 3. Data base storage, early 1970's.

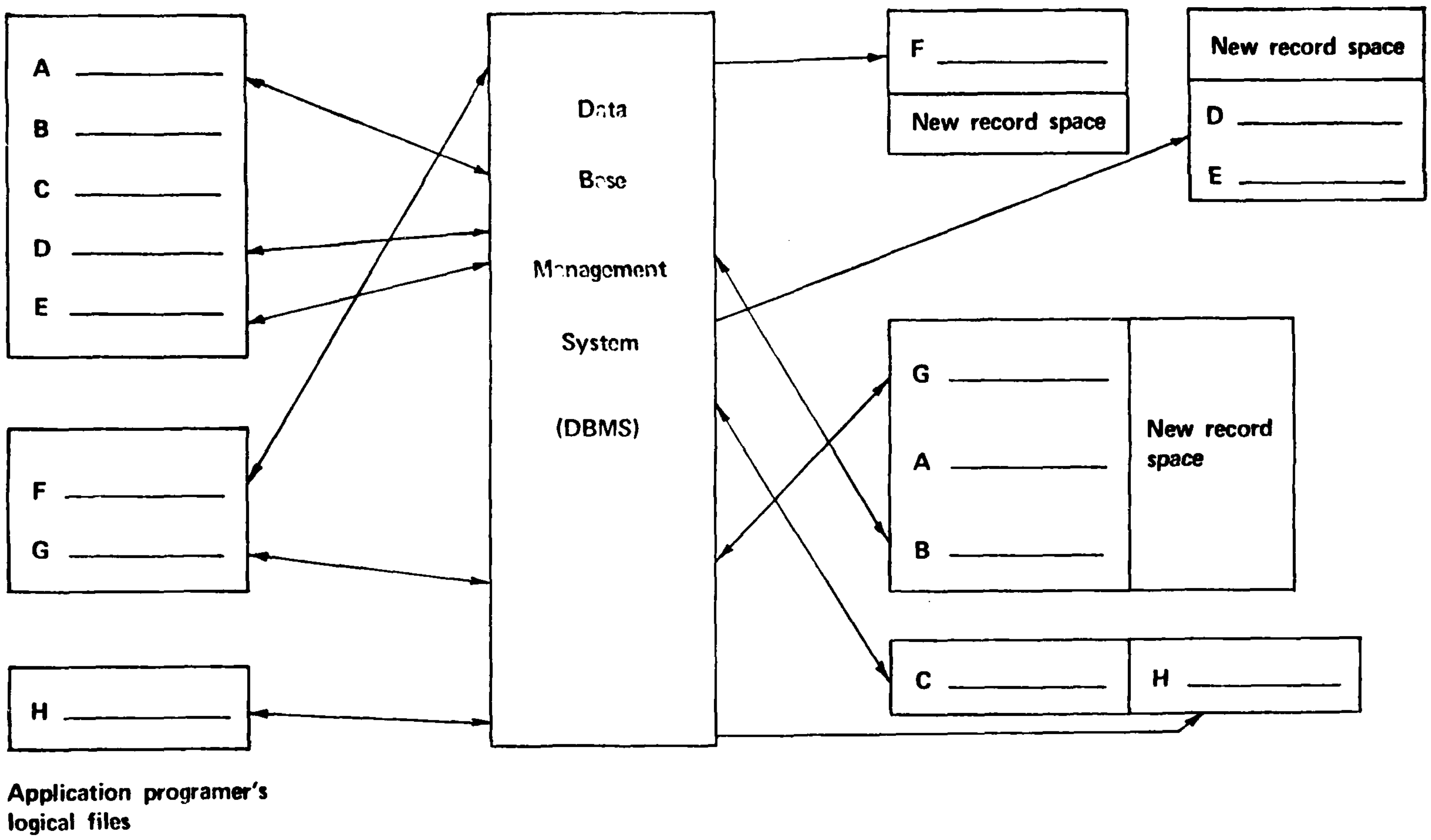

Figure 4. Current data base management system logical and physical data independence.

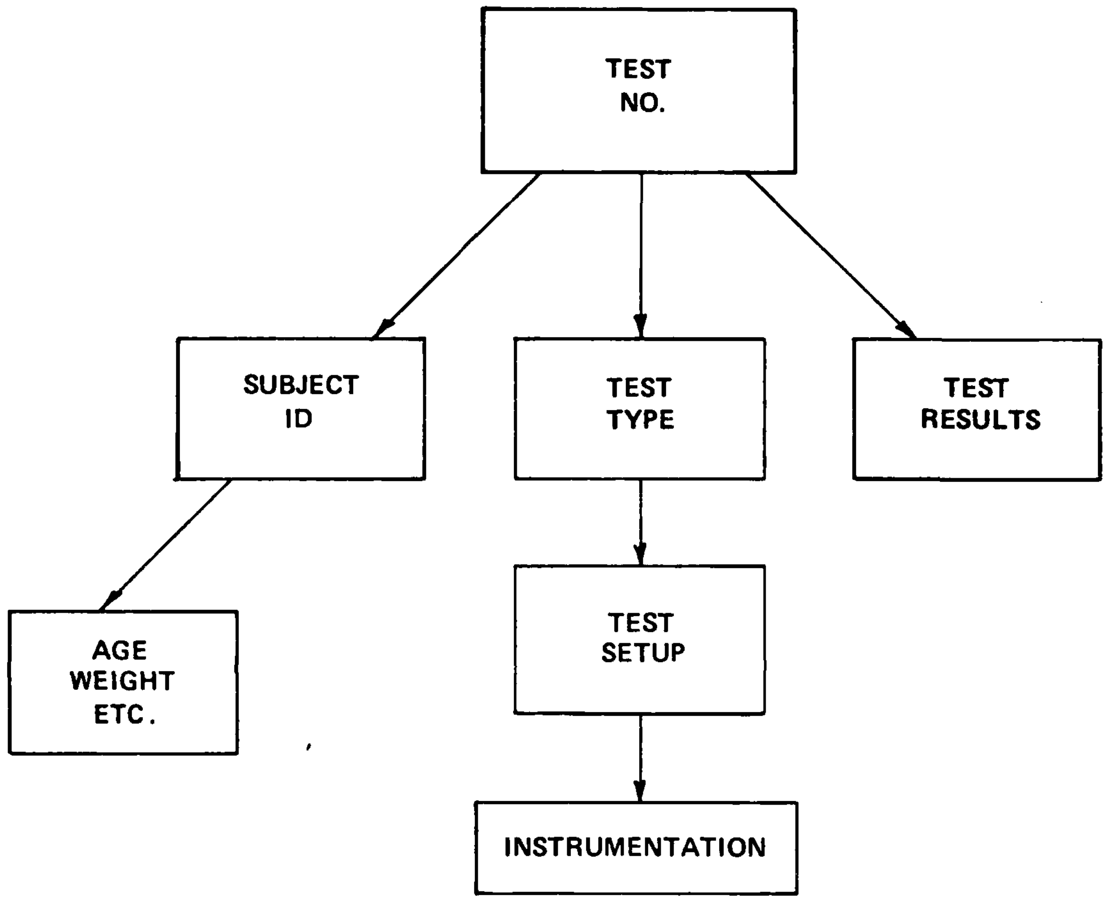

Figure 5. Hierarchical structure - search on test number.

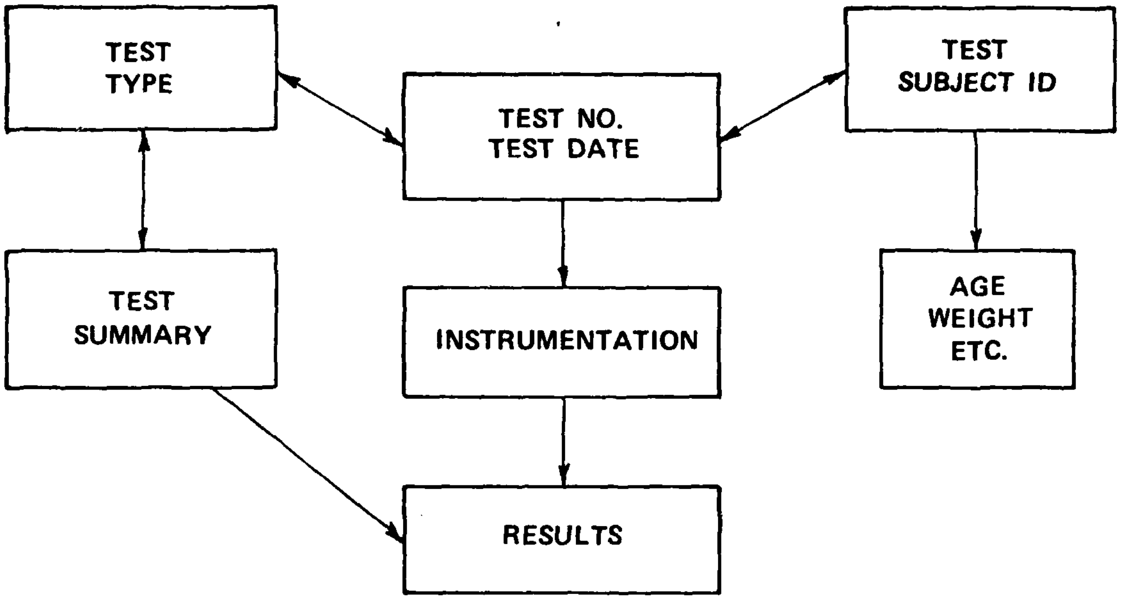

Figure 6. Network or plex structure interrelated data, can search test type, test summary, test number, test date, and subject ID files.

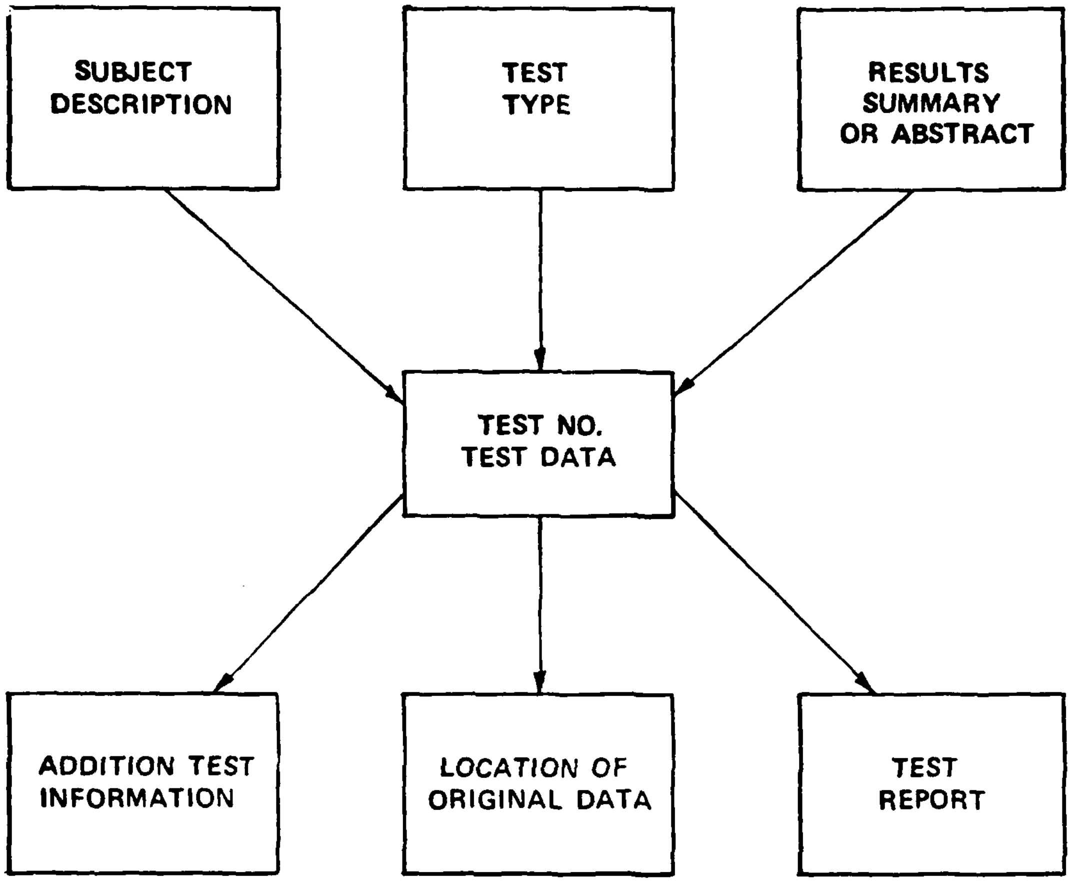

Figure 7. Inverted file structure - can search test subject, test type, and results files to find the desired test data.

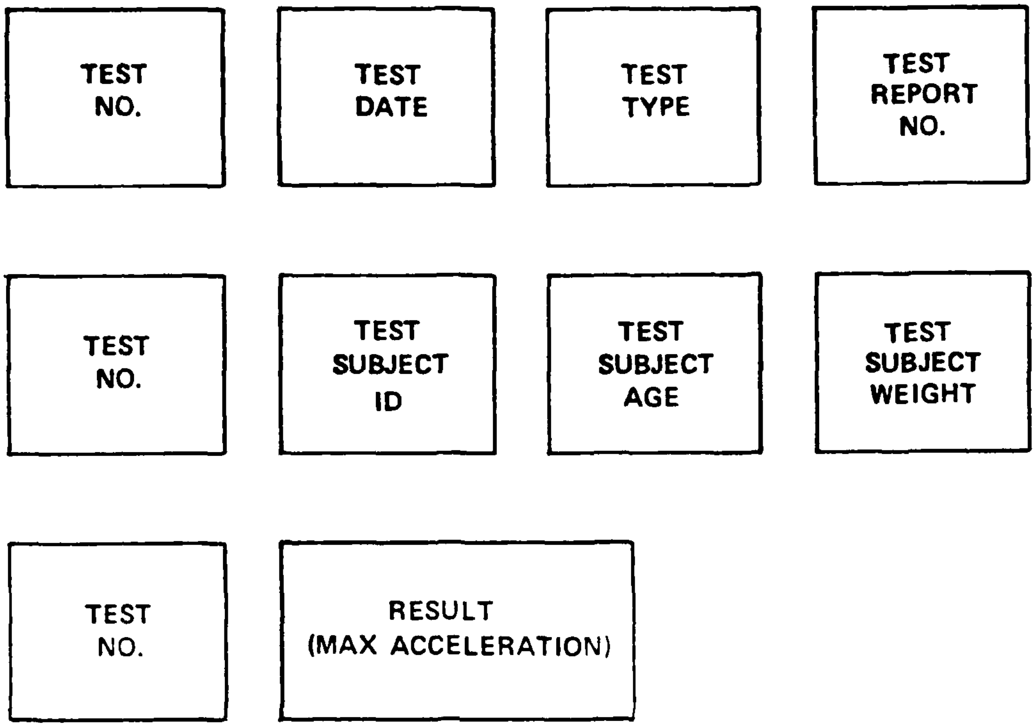

Figure 8. Relational structure - tables of numeric data are keyed together with an identifier, in this case the test number is the identifier.

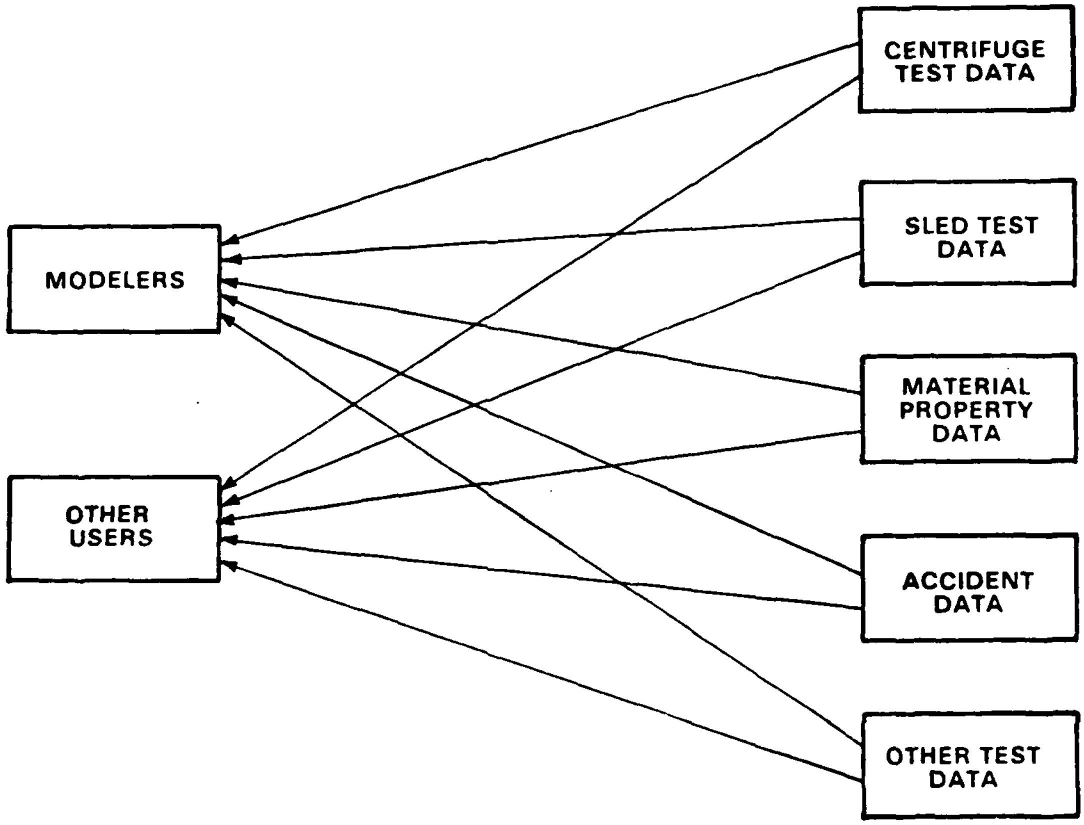

Figure 9. Current data transfer.

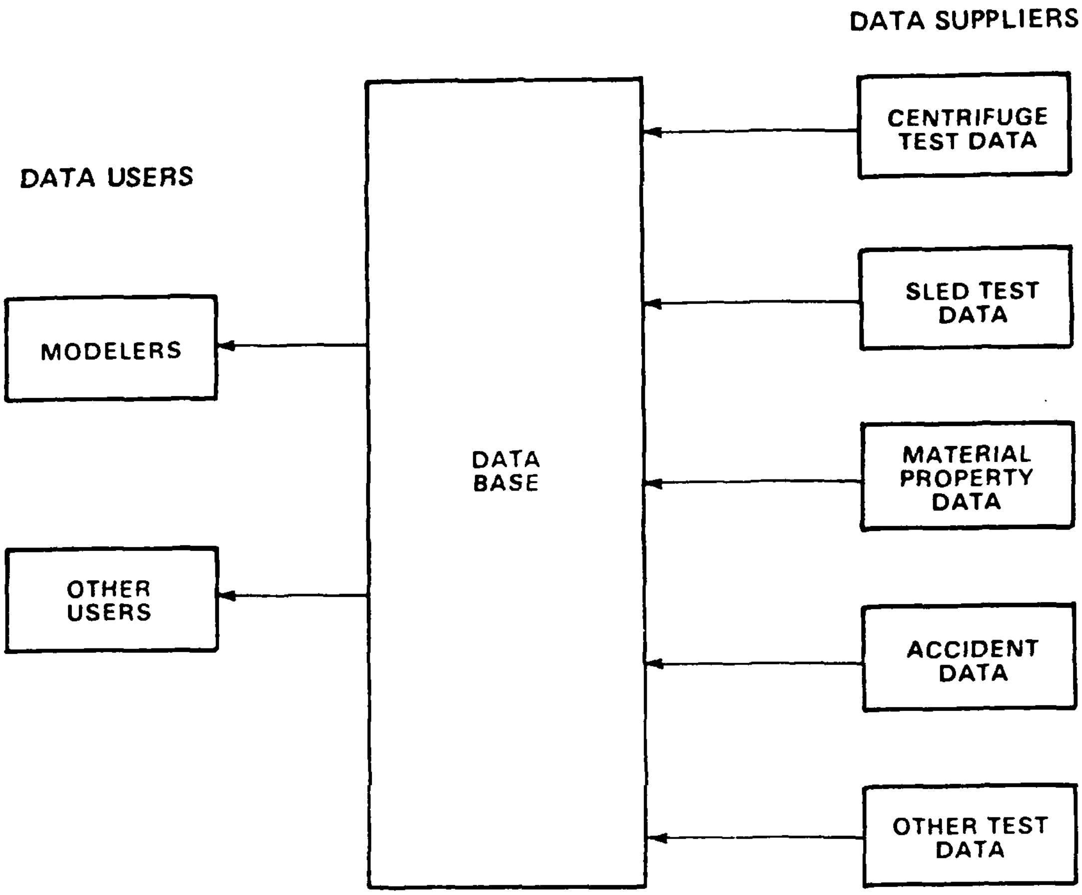

Figure 10. Transfer of data into and out of the data base.

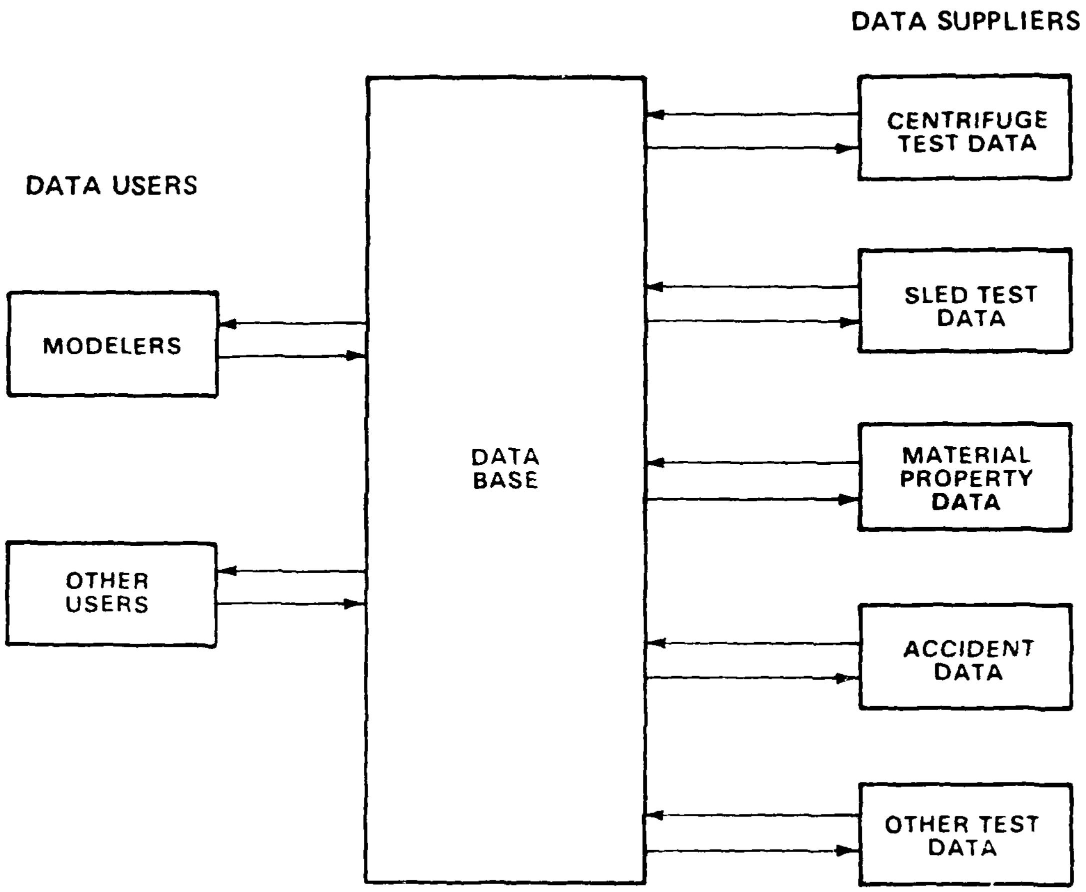

Figure 11. Improved data transfer - the data base provides services to the data suppliers and interfaces directly with the data user's programs, generating additional biodynamic information.

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